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MODEL PROJECTS - PART OF CIVIL ENGINEERING CURRICULUM

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This paper presents the methodology used in incorporating model projects into two fundamental civil engineering subjects, Engineering Mechanics and Steel Structures, at Queensland University of Technology. Students in small groups were required to analyse, design and build the lightest / most efficient model structures such as steel columns or bridges made of spaghetti, drinking straw, paddle pop sticks and balsa wood for a given design loading/target capacity. Details from introduction to evaluation of this teaching strategy, developed as part of the University's quality teaching programmes, are presented.

INTRODUCTION

Engineering Mechanics and Steel Structures are two basic subjects taught in the first and second years of the four-year civil engineering degree course at Queensland University of Technology (QUT). Engineering Mechanics is a common first year subject to all other disciplines of engineering. These subjects, in particular, Engineering Mechanics, are the basic building blocks for the entire engineering course. Therefore it is important that they are taught well and that students actually learn well and understand these basic building blocks (Karim, 1991). However, students' performance in these subjects in the past has not been good. Students appear to have difficulties in understanding basic concepts. This may lead to higher drop-out rates. Similar observations have been made by Karim (1991) and DEET (1988).

Most engineering students choose to do engineering because they believe engineering involves solving real life problems (Wheway, 1991). Routine assignment problems are uninteresting and boring to engineering students, and do not encourage creativity or original thinking. They do not expose the students to solving realistic problems. Some universities, like QUT, do have design oriented subjects in the third and fourth years of the course, but it is somewhat late as students have to do a number of basic subjects in the first two years which may appear very abstract and of no use to them. Thus it is particularly necessary to teach the basic engineering subjects with strong reference to real life problems. In recent times engineering educators (Wheway, 1991) have taken a project-based approach to teaching basic subjects in order to relate basic concepts to real engineering problems. Such an approach is expected to improve students' understanding, motivation and creativity. This approach has been taken by the authors in teaching Engineering Mechanics and Steel Structures at QUT. Students in groups were required to analyse, design and construct model bridges made of spaghetti, balsa wood, drinking straw and paddle pop sticks, and steel columns for given specifications. Heywood and Weeks (1991) also used a project-based approach, but for a higher level subject.

TRAC PROJECT

QUT's Academic Staff Development Unit (ASDU) has a number of projects to improve the quality of teaching. The projects described in this paper form part of ASDU's ongoing project on reflective teaching, the TRAC (Teaching, Reflection, Action and Collaboration) project (Weeks and Scott, 1992). TRAC provides a framework for academics to action research the problems of implementing alternative approaches to teaching in higher education. The first author's participation in the TRAC project can be summarised as follows.

Teaching: Engineering Mechanics and Steel Structures
Reflection: As a lecturer, I was concerned about the poor performance of the students at the final examination. The usual lecturing and tutoring approach was the sole teaching strategy used in the past. I thought there must be something we could do better as lecturers.
Action: I decided to conduct model projects/competitions as part of the subjects
Collaboration: I have collaborated with other staff in my school who are lecturing this and other similar subjects. I have consulted the staff from ASDU and the library in order to improve the project.

ENGINEERING MECHANICS PROJECT

First year engineering students were told that as professional engineers they have to design and construct the lightest bridge to carry a 0.9 kg truck across a river of width 650 mm. The bridge also had to carry a 80 mm wide articulated aluminium roadway which has the same mass. Roadway was 100 mm above the abutments. Students had to use only raw materials such as spaghetti to build the most economical bridge. Figure 1 shows the details of the river crossing, roadway and truck. The truck was released from the top of the ramp on the left, and was expected to get to the other side without breaking the bridge. Students were required to work in groups of five. Each student was given a handout with details of the project under the headings of the Problem, Specifications, Design Approach, Building the Bridge, Testing your bridge and Assessment.

In the past other universities and the Institution of Engineers, Australia have conducted the spaghetti bridge competition for first year university students and school children. However, at QUT it was introduced for the first time as part of a basic subject, and was assessed like a later year design project. This year we are conducting this project for the third time. Each year we have changed the parameters such as raw materials from spaghetti to drinking straw and paddle pop sticks or balsa wood. In the last project the mass of truck was also changed to 10 kg, and the type of bridge was restricted to balsa wood girders.

In each case a total of 80 bridges were tested in a public domain at QUT with students and staff from all the faculties watching. During the testing video and photographs were taken, and a commentator described the testing and results to keep everyone informed and amused. Senior civil engineering staff members formed a panel of three judges who assessed the project based on

- Innovative Structural form 15%
- Aesthetics of the bridge 10%
- Analysis, Design and construction of bridge 25%
- the efficiency of the bridge 35% (lower the weight better the marks)
- the Report 15%

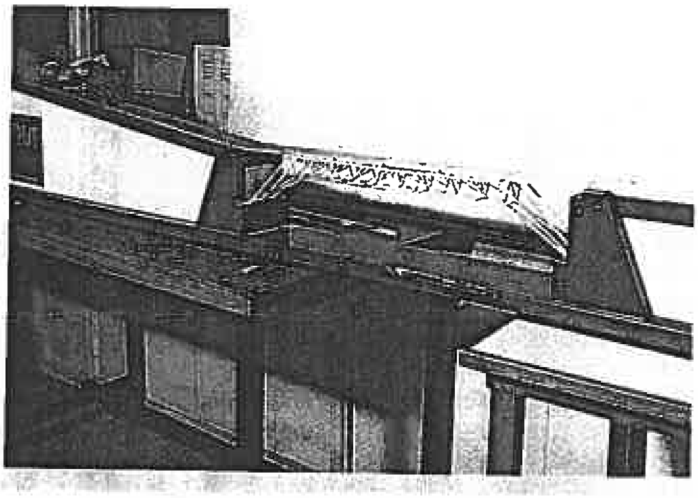


Figure 1. Testing of Model Bridges

After the testing students had to face the judges with a big smile and the unbroken bridge to explain how they got it right, or with a sad face and broken pieces of the bridge to explain what went wrong (see Figure 2). Both testing and judging were considered very important aspects of the project. After four hours of testing and judging, the lightest bridge builders were announced as the winners. Figure 3 (a) shows the winning entry last year. A separate category of the most aesthetic bridge winners was also announced on the same day (Figure 3 (b)). However, the overall performance in the project was determined after the marks had been allocated for the efficiency of the bridge based on the weight and for the report. Marks for the efficiency depended on the minimum and maximum weight of the bridge, entered into the competition.

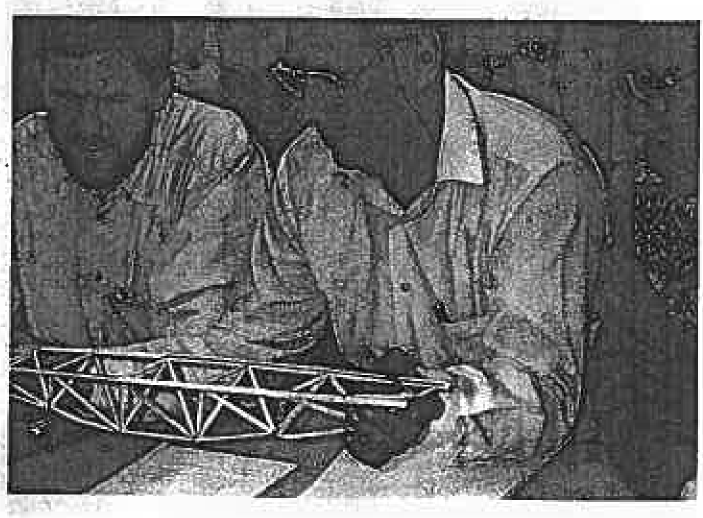
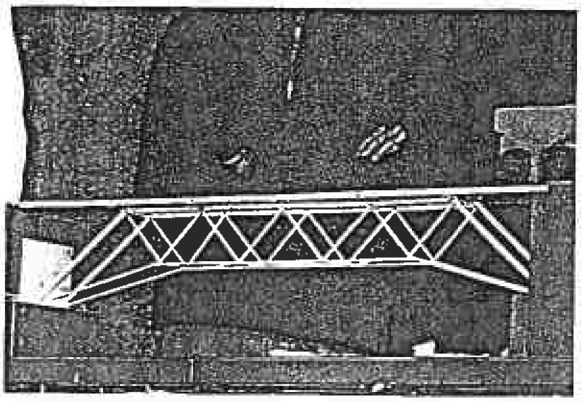
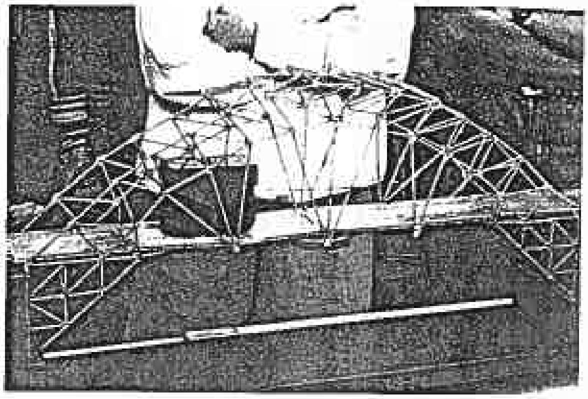


Figure 2. Judges at Work



(a) The Lightest Bridge



(b) The Most Aesthetic Bridge

Figure 3. The Winning Model Bridges

STEEL STRUCTURES PROJECT

This project was introduced as part of the second year subject, Steel Structures. Students were told that they are the Product Development Engineers attached to a steel framed housing manufacturer. Students in groups of four were required to investigate the use of open, unwelded, cold-formed thin-walled steel sections as 1 m long columns (studs) with simply supported end conditions for steel framed housing using different geometry of section, grades and thicknesses of steel. Their objective was to develop the most efficient section for 1m long columns of three different capacities of 20, 40 or 60 kN. The most efficient section was considered as the one which had the greatest axial compression capacity per unit weight as the fabrication cost was considered approximately the same for all sections using the equipment available at QUT. Equipment at QUT has some limitations and the students were therefore required to design columns which were constructable. Each student was given a handout with details of the project under the headings of the Problem, Procedure, Design Approach, Testing and Assessment.

Students first chose the thickness and grade of steel and geometry for a given target capacity. They calculated the member capacity according to the steel code, based on which they attempted to delay/avoid the possible buckling and yielding modes of failure of the chosen sections. Section geometry and other parameters were changed until the most efficient section was obtained.

A total of 22 columns were tested in axial compression to failure on our Structures laboratory testing machine (see Figures 4 and 5) in front of 90 students and a judging panel of three staff members. Each submission was assessed based on

- Innovative section 10%
- Development of the proposed section, based on the design approach used and the ratio of experimental capacity to target capacity 40%
- Efficiency of the section, based on the ratio of experimental capacity to weight of member 35%
- Report 15%

Testing, judging on the day of testing and final assessment were carried out in a similar way to that in the Engineering Mechanics project. Figure 5 illustrates the various buckling modes observed during the project. Students are unlikely to encounter such graphical illustration in a normal course of study.

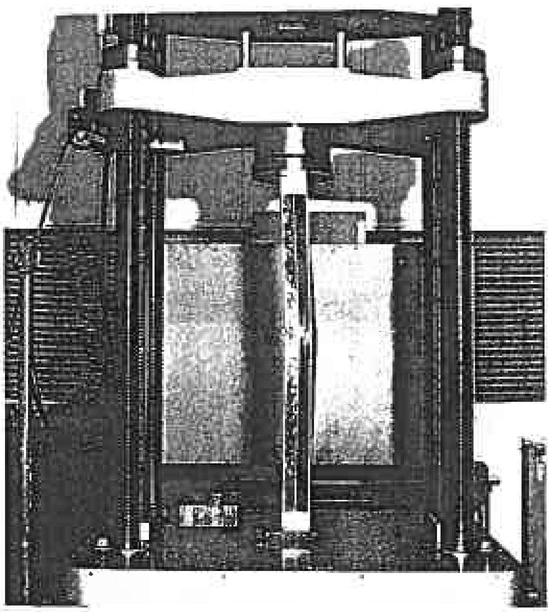
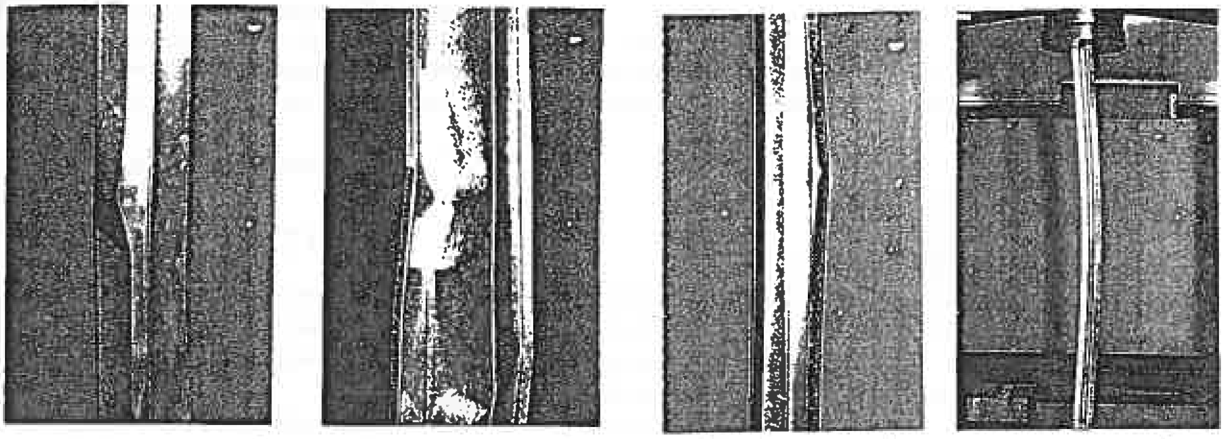


Figure 4. Testing of Steel Columns



(a) Local Flange Buckling (b) Local Web Buckling (c) Distortional Buckling (d) Global Buckling

Figure 5. Steel Column Buckling Modes[8]

LIBRARY WORK AS PART OF PROJECTS

The School of Civil Engineering at QUT has a well developed programme of library instruction for its students at all levels (Bruce and Brameld, 1990). This involves a first year orientation to the library and library skills, and a graduated development of skills at later years. However, one of the serious difficulties experienced by students and teachers in the past has been the 'gap', between learning to use the library in first year and the actual need to use the library for 'real' engineering subjects in later years. The introduction of the real bridge building assignment into the first year curriculum provided an excellent avenue for ensuring that student would have the opportunity to use the library skills acquired during the earlier stages of their course.

The aims of the library work built into the projects were to remind students of information sources to which they had already been introduced, to encourage them to use information sources and libraries other than their own, and to expose them to the process of learning and using library information in real problem solving. Essentially students were asked to find out what different types of bridge structures and steel columns were possible, then to select the most appropriate structure or section for their task. In order to accomplish this they needed basic information about these structures and lots of pictures to provide them with ideas of possible forms from various encyclopaedia and text books. In their assignments students were given a number of pointers to appropriate information sources to ensure successful experiences which would consolidate and build on skills acquired elsewhere.

EVALUATION OF PROJECTS

Students' evaluation

Students' evaluation of the project was obtained through surveys carried out at the end of the projects. A questionnaire with simple, open ended questions similar to that used by Heywood and Weeks (1991) was answered by students. The results are summarised as follows.

Engineering Mechanics (191 respondents)

	YES	*NO*
1. Did you participate in the project?	189 (99%)	2 (1%)
If yes, did you enjoy it?	170 (89%)	21 (11%)
2. Did the project provide you a better understanding of Eng. Mechanics?	166 (87%)	25 (13%)
3. In your opinion, should the project be a regular feature of Eng. Mechanics?	183 (96%)	8 (4%)

4. How much did the project cost your team? Nothing to $20; on average $4 to 6

5. Things you liked about the project: (students' own words)

Designing, building and testing of the bridges. *helped to learn basic design process; learning about a* ***real life problem*** *with a bit of fun; practical use of theory to do real things; creativeness and the competitive nature of the project; challenging and interesting, writing report; got to know other people; group work; suspense of whether my design would work; sense of achievement and satisfaction*

6. Your suggestions to improve the project:
Smaller groups; more time and marks for project; more marks for aesthetics; revise assessment and loading criteria; longer span and heavier truck; clear definition of adhesives and pins that can be used; better venue for testing; test rig for trial runs; provide standard material; allocate lecture time for project

Steel Structures (78 respondents)

	YES	*NO*
1. Did you participate in the project?	77 (99%)	1 (1%)
If yes, did you enjoy it?	66 (85%)	12 (15%)
2. Did the project provide you a better understanding of Steel Structures?	74 (95%)	4 (5%)
3. In your opinion, should the project be a regular feature of Steel Structures?	74 (95%)	4 (5%)

4. On average how much time did each member of the group spend on the project?
Range 1 to 48 hours - Typical 4 to 6 hours

5. Things you liked about the project: (students' own words)
Everything!; it was great; *thought provoking, fun, enjoyable and interesting, practical, challenging and educational; understood why we are doing these things and this helped in learning; gave a better understanding of theory and various formulae; applying theory to a real life application;* ***made me learn;*** *designing and then testing was a good way to see the effects of load and a number of buckling modes, and compare load capacities in different columns; design and testing enabled confusing theory to be put into practice; testing showed how steel actually failed under compression; it made me realise the compression capacity of a cold-formed steel column; it gave me a whole lot of perspective on what or how cold formed steel can be used in future house and construction development projects; testing - good break/change from tutorials and fun to watch the failures and successes; ability to design a column of any shape to carry a particular load;* ***it is always good to design something yourself and see the actual member made and then wreck it; My column worked! the ability to actually see something I designed work as it was supposed to.***

6. Your suggestions to improve the project:
A prize; more guidance and information at the start; better fabrication capacities in the laboratory; half the class design columns and other half beams; revise marking scheme; check our calculations before testing; a trial test; smaller groups, do the project earlier in order to get feedback; reduce number of steel grades

<u>Our Evaluation and Reflection</u>

Both projects were of excellent teaching value, and extremely rewarding. The students' evaluation clearly reflects this. More than 95% of students indicated that the model projects should be a regular feature of the subjects, and more than 85% said that projects improved their understanding of the subjects. More importantly, more than 85% of students said they enjoyed doing the projects. Students' comments under "Things you liked about the project" above speak for themselves. They are very encouraging and tell us something of the value of these projects in these **early years** of the course.

Students learnt independently about **all** aspects of analysis, design, construction and testing of bridges and steel columns, i.e. the full design process. One steel project student commented that he can now do a steel column design blind-folded. Staff only had to advise them occasionally throughout the project. The projects simulated realistic design exercises, and thus acted as a nexus between theory and practice. They gave an opportunity for students to deign something 'real' unlike the usual assignment problems. Students tested the construction materials under appropriate loading to obtain strength properties, and selected the materials and the structure layout to suit, i.e., they learnt the material selection process. They realised the need to evaluate alternatives in design, the importance of quality of construction and constructability, the need to work as a team of professionals, the usefulness of research and library skills and many other important concepts, which could have never been achieved through the usual lectures. Some very important and difficult concepts such as various buckling modes of columns (see Figure 5), lateral stability of bridges and bracing requirements and the like were fully understood by the students **without any additional formal lectures** on the topics.

Students learnt significantly during the projects. Engineering Mechanics project taught the students that joint designs are as important as to member designs, and that dynamic loading causes more stresses. They determined that buckling capacity of compression members decreases with length whereas tension strength is independent of length. Thus they attempted to design a bridge which had fewer and shorter compression members when they found spaghetti to be weaker in compression than in tension. They understood the classification of determinate and indeterminate structures. Many students made their bridge determinate so that they could analyse it. But if they wanted indeterminate bridges they tested them to determine the adequacy of them - a usual research procedure. In the Steel Structures project students learnt about the difference between cold-formed and hot-rolled steel structures, and the need to use separate design codes. They understood the real column behaviour including various types of buckling modes and the reasons.

Both projects revealed what these young students could do when given the opportunity. For the bridge project one group wrote a BASIC program to analyse their bridge truss using method of joints, and for the steel column project many groups used spreadsheets to optimise the geometry of the section. Some first year project students tested trial bridges at home by simulating the specified truck loading. For the steel project students used paper/cardboard models loaded with books to optimise their geometry. Innovative bridges and column sections were designed by the students (see Figures 3 and 4).

If all four stages of the Kolb's learning cycle (Reflective observation- watching, Abstract conceptualisation-thinking, Active experimentation-doing, Concrete experience-feeling) are used in teaching, students will learn well, understand and enjoy it (Stice, 1987). Our projects allowed us to include all these four stages in teaching, and thus they were successful. Stice (1987) further says that engineering students are 'convergers' who are strong on abstract conceptualisation and active experimentation (two stages of Kolb's learning cycle). They are interested in practical uses for ideas and theories, and are not likely to work hard or effectively unless they see apparent use. These claims explain why the introduction of Mechanics and Steel Structures projects improved the learning of the first and second year engineering students.

Library research, drafting and technical report writing skills also improved significantly as reflected by students' final reports. Some reports were so comprehensive that they were like the final year theses. These projects allowed both the stage of learning to use the library in early years and that of actually using it for real engineering problems to concur, and thus eliminating the gap previously experienced.

CONCLUSION

Model projects which involve analysis, design and building of model structures such as bridges made of spaghetti, drinking straw, paddle pop sticks and balsa wood and steel columns were introduced in two basic civil engineering subjects in order to improve the performance of students. These projects were successful in improving the understanding of basic concepts, enabling deep learning, broadening knowledge, and encouraging creativity. They simulated a realistic engineering exercise in the early years of the course which the students enjoyed very much. Students learned to perform their duties as part of a team of professionals without much staff supervision. A number of other benefits and improvements have been identified.

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